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NUMERICAL ANALYSIS OF LOW SPEED PRE-IGNITION AND KNOCK PROCESS IN DOWNSIZED TURBOCHARGED DIRECT INJECTION ENGINES WITH ETHANOL-GASOLINE BLENDS

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ABSTRACT−The feasibility of the calculation model and calculation methods is verified by engine bench test and visual rapid compression machine (RCM) test as reported in this paper. Using AVL software FIRE, the processes of low speed pre-ignition (LSPI) and super knock triggered by the oil particles have been studied by numerical analysis of downsized turbocharged direct injection (DI) engines with different proportions of ethanol-gasoline blended fuel and different operating conditions (1200 r·min^{-1}, 1600 r·min^{-1}). The results show that the E10 and E20 fuel engines produce super knock successively; with the increase of the ethanol proportion, even if the LSPI phenomenon (1200 r·min^{-1}) still occurs and leads to the subsequent knock process, the pressure rise amplitude is obviously reduced, and no super knock phenomenon occurs at the time when the ethanol proportion reaches 30 %; there is no LSPI phenomenon in the engine after the blending rate is above 50 %. The overall conclusion is that there must be LSPI before the super knock in ethanol-gasoline blended fuel downsized turbocharged DI engines, but the LSPI not always lead to super knock. With the increase of ethanol proportion, even if the LSPI occurs in the engine cylinder, it only causes regular knock.

KEY WORDS : Low speed pre-ignition, Super knock, Ethanol-gasoline blended fuel, Numerical analysis, Downsized turbocharged direct injection engines

NOMENCLATURE

RCM : rapid compression machine
LSPI : low speed pre-ignition
DI : direct injection
FFV : flexible fuel vehicle
CFD : computational fluid dynamics
ECU : electronic control unit
CA : crank angle
TDC : top dead center
BDC : bottom dead center
ATDC : after top dead center
RON : research octane number
BTDC : before top dead center

1. INTRODUCTION

Vehicle emissions are one of the most important factors of air pollution in major cities all over the world because of the rapid increase in car usage and number of licensed vehicles. Adding a certain proportion of ethanol into gasoline could reduce the harmful emission of gasoline engine effectively (Liu *et al*., 2012). At present, the ethanol-gasoline blended fuel, is widely used in Brazil and the USA. Both countries produce ethanol as a fuel substitute by using the surplus sugarcane or maize as raw materials in order to develop their own FFV technology. The USA is the country with the largest production of vehicles with ethanol-use adjusted engines, and also the highest consumption of vehicles ethanol for vehicle use in the world and the ethanol-gasoline blended fuel is already widespread by more than 90 % across the USA (Energy Future Coalition, 2011). Brazil is the second-largest ethanol producer and 20 % of the cars use pure ethanol directly. Eleven pilot provinces in China have started to use ethanol-gasoline blended fuel. Furthermore, fifteen provinces, led by Beijing, Tianjin and Hebei, will begin to promote the use of ethanol-gasoline blended fuel mixtures in 2019 (State Council Executive Meeting, 2018). China aims to realise the full use of vehicle ethanol by 2020, and the large-scale production of cellulosic ethanol by 2025. These ambitions are stated clearly in the document entitled ‘Implementation plan of expanding the production of biofuel ethanol and promoting the use of vehicular ethanol-gasoline blended fuel’ which has been jointly issued by 15 government departments of China including the National

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